

## WIND POWER

*Note*

*In 1995 wind power created some 9,000 jobs in Denmark, including jobs with Danish turbine component suppliers*

*The impact on global employment from the manufacturing process is some 12,000 jobs*

*The installation of Danish turbines worldwide created another 4,000 jobs*

*Danish wind turbine manufacturers supply approximately half of the nameplate generating capacity in the world market. One may therefore estimate worldwide employment in the windpower industry to be in the range of 30,000 to 35,000 jobs in 1995*

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*Editor: Søren Krohn*



VINDMØLLEINDUSTRIEN  
Vester Voldgade 106  
DK 1552 Copenhagen K

Tel +45 3373 0330  
Fax +45 3373 0333  
E-mail: danish@windpower.dk  
Internet: www.windpower.dk

## EMPLOYMENT IN THE WIND POWER INDUSTRY

This publication analyses the employment in the Danish wind power industry.

Economists who are familiar with input-output analysis may skip this page.

The employment calculated in this note is the *total direct and indirect employment created by the manufacture of wind turbines and wind turbine components in Denmark, plus installation of turbines, research, consultancy work etc.*

Thus the analysis includes the employment with turbine component suppliers (related to the supply of components to turbine manufacturers). In addition, the direct and indirect employment created by Danish exports of turbine components is included in the final figure.

Component suppliers, of course, use Danish sub-component suppliers as well.

In order to track the employment thus created in all links of the value added chain one may make use of the so-called input output tables from the central bureau of statistics, *Danmarks Statistik*.

These tables subdivide the Danish economy into 117 sectors.

For each sector one may see the inputs to the manufacturing process and the outputs divided according to supply and demand sectors. The tables are revised every year. In addition, *Danmarks Statistik* recalculates

the tables so as to enable the user to see directly how much employment is created on average whenever sales of 1 million DKK are manufactured.

The wind turbine industry is not included directly in the tables. It is part of the industrial machinery sector. This paper analyses whether the wind turbine manufacturing sector differs significantly from the average of the industrial machinery sector.

Finally, the paper estimates how many jobs are created worldwide by the Danish wind power industry. This calculation includes jobs created in e.g. Germany, Finland and Austria through Danish component imports. In addition, the paper calculates the number of jobs created by the installation of Danish turbines abroad.

*Another* type of economic analysis focuses on what happens in the rest of the economy if production increases in a certain industry. That is quite another type of analysis which so to speak accounts for the fact that the baker may lose his job if the wind turbine worker loses his job, and decreases his consumption of Danish pastry. The analysis in this paper is *not* concerned with that phenomenon.

This note *only* accounts for the demand for employment originating from the manufacturing of wind turbines and components, but not the activity impact on the rest of the economy.

## 1 DEFINITIONS

Production in the Danish windpower sector includes:

1.1 Wind turbine manufacturers' production (direct employment) including purchases from Danish subcontractors (indirect employment) and their subcontractors throughout the production chain.

1.2 Production of turbine components for foreign manufacturers including purchases from Danish subcontractors throughout the production chain.

1.3 Turbine servicing, publicly funded research, and windpower related public administration.

1.4 Installation of wind turbines in Denmark.

## 2 GROSS OUTPUT OF THE WIND POWER SECTOR

In order to calculate employment in the sector, one has to find the gross output of the sector at factor cost.

### 2.1 Wind turbine factories

According to the 1994 annual statistics from the Danish Wind Turbine Manufacturers' Association the seven large turbine manufacturers had total sales of 2,334 million DKK. This figure includes larger components or kits for turbines which are assembled abroad. The figures also include turbine service in Denmark and abroad. Since servicing is more labour intensive per DKK of sales it would be desirable to split the figures into service and manufacturing. Unfortunately this is not possible. The employment figures may therefore underestimate the true employment somewhat.

Sales from small turbine manufacturers (25 kW or less), independent turbine service companies, and their suppliers are not included in this part of the analysis. It is assumed that employment in these sectors is relatively limited. An estimate of direct and indirect employment in these sectors has been included in the »other« group related to research, consultancies, etc.

### 2.2 Direct exports from Danish subcontractors

A survey conducted in August 1995 with the Danish subcontractors revealed significant export sales to foreign turbine manufacturers. When we use the term *export shares* in this section, we refer to *direct* exports from the companies. Indirect exports have already been accounted for in the turbine manufacturers' sales in section 2.1.

Total Danish sales to foreign wind turbine manufacturers are clearly larger than whatever is supplied by the wind turbine specialist companies. The reason why these deliveries are not included in this survey is that it concentrates on direct spin-offs from *Danish* turbine manufacturing. Thus we avoid double counting when we generalise our results to the global market.

#### 2.2.1 Exports of rotor blades

Denmark currently has only two manufacturers of rotor blades of any reasonable size: *LM Glasfiber* (which is the largest rotor blade manufacturer in the world), and *Vestas Wind Systems* which only manufactures blades for its own use. *Vestas'* gross output value of rotor blades by definition is zero, since the figure has already been included in the turbine manufacturers' sales in section 2.1.

*Turbine sales were 2,334 million DKK in 1994*

*Sales figures exclude small turbine manufacturers and independent turbine service companies*

25 per cent direct export share for rotor blades

In the case of rotor blades one may estimate a direct export share of some 25 per cent in 1994. The figure has been estimated cautiously, particularly if there are price differentials between exports and domestic sales. In that case one would assume that the price is higher for exports, since volume rebates may be assumed to be larger with the very large Danish customers. Finally, there may have been some further advance in export shares in 1995.

50 per cent export shares for electronic systems and remote surveillance equipment

### 2.2.2 Exports of electronic systems and remote surveillance equipment

For *Electronic systems and remote surveillance equipment* the export shares are astonishingly high. 50 per cent would be a reasonable estimate, judging by the answers from all major suppliers. Some have even abandoned the Danish market altogether in favour of foreign customers. (The market may be more lucrative and less competitive abroad than domestically).

25 per cent export share for brakes and hydraulic systems

### 2.2.3 Brakes and hydraulic systems

Brakes and hydraulic systems have an export share of some 25 per cent, using a somewhat conservative estimate.

15 per cent export share for towers

### 2.2.4 Towers

Towers have an export share of 15 per cent, since tower exports from *Vølund Stålteknik* (bought by Vestas on 1 January 1995) by definition are set at zero. This figure may be somewhat conservative, since some old customer relationships may have continued temporarily.

Total direct component exports for foreign manufacturers approx. 300 million DKK in 1994

Total exports of components for foreign wind turbine manufacturers were some 300 million DKK in 1994, calculated on the basis of export shares and component values estimated in the input-output analysis in table 2 below.

A further 150 million DKK for this »other« group

## 2.3 Independent turbine service companies, research, public administration, etc.

There is no need for an accurate assessment of gross value added (sales) in this sector, as it is easier to estimate employment directly on the basis of common knowledge about the sector. (Indirectly, however, from the cost estimates for installation of turbines, service prices etc. one may estimate a total amount of 150 million DKK).

Approximately 300 persons are employed in service industries related to wind power

Some 300 persons are estimated to be employed in this sector in 1995. *Risø* national laboratory alone employs some 60 persons in this area. A larger number of persons (working with windpower) are employed in consultancy firms, engineering firms, financial institutions, and insurance companies. In addition, power companies, independent service firms, public administration and private associations have a number of employees working on wind power.

The figure does not include supplies to the turbine manufacturers

The estimate does not include persons whose services are purchased by the turbine manufacturers etc., since these figures are already included indirectly in their sales figures (1.1 and 1.2). Finally, note that employment is calculated in *persons*, not by full time employed persons (assuming average sectorial working hours).

## 2.4 Installation of wind turbines in Denmark

Turnover related to sales of turbines in Denmark may be estimated from the key figures published by the Danish Energy Agency in its report on the economics of privately owned wind turbines. The figures in table 1 have been updated to 1995.

Domestic sales from the seven large Danish turbine manufacturers were 313 million DKK in 1994. This includes turbine servicing. Assuming that the total amount is related to sales of turbines we overestimate installation costs. On the other hand, the survey does not account for power company costs for grid reinforcement, which theoretically should have been included. All things considered the employment estimate may be on the low side, if one believes power company statements on costs. There is therefore a need to round up the final result. We therefore assume a total employment of 50 persons due to grid reinforcement.

On the basis of the column with the value of the different operations involved in *installation* work, turnover for 1994 may be estimated to be 75 million DKK, plus grid reinforcement. For 1995 the growth on the home market is estimated at 50 per cent, yielding a total installation turnover somewhat above 100 million DKK.

Each share of the installation work has been assigned to a specific sector in the input-output model. The *employment multiplier*, i.e. the factor used to multiply gross output to obtain total direct and indirect employment in Denmark is available until 1993.

The multipliers have therefore been adjusted for another 1-2 years using the average growth rate of the multiplier in the previous three-year interval from 1990 to 1993. The telecommunications equipment multiplier has been adjusted from 1991, as the 1993 multipliers are not yet available at the 117-sector level, but only on the aggregate (27) sector level.

### 3 A SIMPLE ESTIMATE TO CHECK CALCULATIONS

At this point we could choose to base our calculations directly on the 2,334 million DKK, and add the 319 million DKK for component exports from the supplier group, yielding a turnover of 2,653 million DKK. For 1995 a growth rate of 45 per cent is assumed, with a total turnover of 3,847 million DKK.

The central bureau of statistics, *Danmarks Statistik (DS)*, has published an employment multiplier for sector 38000, manufacturing of fabricated metal products, of 2.41 persons employed per million DKK gross output value at current prices. The coefficient needs to be adjusted to 1994 and 1995. During the interval 1990-1993 the employment multiplier for the next higher aggregate industry declined at an annual rate of 5.1 per cent. Using the same annual rate on the 2.41 we obtain multipliers of 1.29 and 2.17 for 1994 and 1995 respectively.

If we consider wind turbines to be an average product of the »manufacturing of fabricated metals«-sector, we may find the result directly, now

**Table 1. Direct and indirect employment from the *installation* of wind turbines in Denmark**

Gross output value per cent of turbine sales	DS Sector No.	Manufactured in DS-Sector	Sales 1994 mill DKK	Employment.	Employment.	Employment.	Total	Total	
				multipl 1993 pers/mill	multipl 1994 pers/mill	multipl 1995 pers	employment. 1994 pers	employment. 1995 pers	
Consultancy work etc.	1.9	83509	Business services	6	2.66	2.57	2.48	15	22
Foundations	4.5	50000	Construction	14	2.86	2.79	2.72	39	58
Electrical installation	1.9	50000	Construction	6	2.86	2.79	2.72	17	24
Grid connection, cable	10.9	50000	Construction	34	2.86	2.79	2.72	95	139
Transformer	2.6	38398	Other electrical supplies	8	0 *)	0 *)	0 *)	0	0
Remote control system	0.6	38320	Telecom equipment	2	2.24	2.13	2.02	4	6
Road	1.3	50000	Construction	4	2.86	2.79	2.72	11	17
Private expenditure total	23.7							181	266
Grid reinforcement, estimated								50	50
<b>Total</b>				<b>74</b>				<b>231</b>	<b>316</b>

\*) Transformers are imported. Consequently, there is only a small employment effect from commerce and transport

We obtain a result of 6,100 directly and indirectly employed in 1994, and 9,000 in 1995...

...but we shall adjust the calculations to account for a possible difference in the import content of wind turbines compared to the sectorial average

The method will underestimate employment

The concept of a »nacelle« is a fiction, but a useful abstraction

Maximum error: 1,200 persons (underestimate)

Rotor blades and towers are gradually becoming cheaper (on average)

Improved correction for resale profit margins

More turbines are exported without towers

We obtain an employment estimate of 6,100 persons in 1994, plus 200 from the installation of turbines, plus 300 in consultancy, research etc., a total of some 6,600. For 1995 we get an estimate of 8,400 persons employed, plus 300, plus 300, i.e. 9,000 persons.

This estimate does not take into account a possibly different (higher) import share in the manufacturing of wind turbines, compared to the average for the sector.

#### 4 ADJUSTMENT METHOD (IMPORTS CORRECTION)

We shall now account for the fact that certain components in a wind turbine, notably gearboxes and generators are not manufactured in Denmark. Consequently they yield little employment, except in commerce and transportation. We begin by estimating the value of the main components of a wind turbine in factor prices. Subsequently, we shall calculate employment in the Danish components.

There is good reason to object, that we are about to underestimate employment using this method. *Danmarks Statistik's* employment multipliers already have built in an average import content for the fabricated metals products sector as a whole. If we eliminate employment from the largest imported components in advance, we shall underestimate the direct and indirect labour content in the manufacturing of nacelles which account for 42.5 per cent of gross output.

The value of the nacelles have actually been calculated residually by subtracting the value of the major components from the gross output value of the turbine. It is clearly pure fiction to claim that the 42.5 per cent is the value of the *nacelle*, since the turbine manufacturer designs, builds and sells the complete wind turbine. This gets us on the track of the error we are about to commit:

A large share of the work unrelated to the nacelle itself is engineering work etc., i.e. labour intensive production. If the import content is zero, direct and indirect employment will be approximately 40 per cent higher than the figure we arrive at. (I.e. the ratio between the global direct and indirect labour content, and the Danish direct and indirect demand for labour). In that case we may underestimate employment by 1,200 persons.

#### 5. WIND TURBINE COMPONENT VALUES

In May 1995 the Danish Wind Turbine Manufacturers' Association analysed component values for a wind turbine at factor prices.

The estimates are averages of a highly varied set of figures. For all practical purposes the figures are an update of figures previously compiled by Risø national laboratory.

The calculations indicate that rotor blades and towers gradually are being optimised so as to contribute to the (real) falling price of wind power capacity.

The figures differ slightly from Risø's. This is partly due to the update to 1995, and a more thorough correction for resale profit margins.

The share of tower costs may be somewhat overestimated in this report, since it appears that more turbine models are being equipped with towers which have been structurally optimised. Furthermore an increasing share of turbines are being exported without towers, which instead are manufactured locally.

This implies that approximately 9 percentage points ought to be assigned to other turbine components. However, this would underes-

More turbines are exported as kits or key components

Employment in the turbine manufacturing companies increased 60 per cent from July 1994 to July 1995, but the real annual increase is smaller...

...we assume a growth rate of 45 per cent in gross output value from 1994 to 1995

Increasing difficulties interpreting exports statistics

timate total employment by 50 jobs only. On the other hand, due to the way direct component exports are estimated (using company export shares) there would be a tendency for the errors to cancel out. Therefore, there is no real need to change the estimate of the value of towers.

Another problem is that an increasing number of turbines are exported as kits for assembly abroad. Gradually, these kits contain fewer and fewer run-of-the-mill components. Since the producer specific key components may be assumed to be part of the labour intensive nacelle components this would also give a tendency to underestimate employment slightly.

Finally, one may reasonably suspect that average prices of turbines are slightly higher on export markets than on the extremely competitive domestic market. This would seem to indicate that the value share of »nacelle etc.« is slightly underestimated.

## 6. GROSS OUTPUT FOR 1994 AND 1995

The column with 1994 gross output values in table 2 has been calculated distributing the gross value of turbines of 2,334 million DKK using the percentages as weights. Direct exports from component manufacturers have been calculated using the direct export shares estimated in section 2.

Employment in the seven turbine manufacturing companies increased by approximately 60 per cent between 1 July 1994 and 1 July 1995. The figures, however, should be adjusted for the fact that Vestas Wind Systems A/S as of 1 January 1995 merged with its tower supplier, A/S Vølund Stålteknik. After this adjustment the growth of employment is 42.6 per cent in a year.

We assume a growth in gross output level of 45 per cent in 1995 over 1994. This would correspond to a production of some 540 MW nameplate capacity.

For component suppliers exports are estimated to increase at the same rate with total exports of some 450 million DKK in 1995.

Due to the fact that an increasing share of Danish wind turbines are exported as components, the total number of megawatts is becoming increasingly difficult to identify statistically. The 540 MW figure may therefore not be directly comparable to actual statistics for 1995.

**Table 2. Direct and indirect Danish employment from the manufacturing of wind turbines in Denmark**

Gross output value per cent of turbine value	DS	Sector	Manufactured in DS-Sector	Turbine gross value 1994	Direct comp. exports	Empl. multi 1993	Empl. multi 1994	Empl. multi 1995	Total empl. 1994	Total empl. 1995
Commerce *)	...	...	Wholesale commerce	...	...	...	...	...	36	50
Generator	4	38398	Other electrical supplies	93	...	0 *)	0 *)	0 *)	0	0
Gearbox	12	38238	Industrial machinery	280	...	0 *)	0 *)	0 *)	0	0
Rotor blades	18	50000	Construction	420	140	2.86	2.79	2.72	1,563	2,209
Tower	18	38138	Structural metal products	420	74	2.30	2.18	2.07	1,077	1,483
Brakes, hydraulics	1.5	38238	Industrial machinery	35	12	2.56	2.43	2.30	113	156
Electronic systems	4	38300	Electrical and telecom equipm.	93	93	2.43	2.31	2.19	431	592
Nacelle	42.5	38238	Industrial machinery	992	...	2.56	2.43	2.30	2,410	3,308
<b>Total</b>	<b>100.0</b>			<b>2,334</b>	<b>319</b>				<b>5,632</b>	<b>7,800</b>

\*) Generators and gearboxes are imported. Consequently, there is only a small employment effect from commerce and transport

Certain multipliers have to be constructed in order to match reality

## 7. EMPLOYMENT MULTIPLIERS

Multipliers in table 2 have been calculated using the same method as in table 1.

Manufacturing of rotor blades is considerably more labour intensive than ordinary plastics product manufacturing. The coefficient for rotor blade manufacturing has therefore been calculated as if it were the construction sector.

Certain coefficients by definition are zero since there is no Danish manufacturing involved.

Two small deviations from the article in VINDFORMATION

## 8 MAIN RESULTS

The main results of this report have been published in the September 1995 issue of VINDFORMATION. There are two minor differences from the tables in this report due to a revision of the adjustment of the employment multipliers. The result is slightly less employment in nacelle manufacturing and slightly more employment in rotor blade manufacturing. Table 3 summarises the results of this report.

In order to extend the analysis backwards in time to 1991, we have to estimate direct exports from component manufacturers. These somewhat uncertain estimates are given in table 3.

Employment has almost tripled during the 4 year interval 1991-1995

Table 3.

Direct + indirect employment from wind power in Denmark					
	Persons 1991	Persons 1992	Persons 1993	Persons 1994	Persons 1995
Wind turbine manufacturing	2,900	2,700	3,650	5,632	7,800
Installation of turbines	300	150	150	231	316
Research etc. cf. section 2.3	<u>200</u>	<u>200</u>	<u>250</u>	<u>300</u>	<u>300</u>
<b>Total (rounded figures)</b>	<b>3,400</b>	<b>3,100</b>	<b>4,100</b>	<b>6,000</b>	<b>8,500</b>

## 9 GLOBAL EMPLOYMENT

Assuming that wind turbine manufacturing abroad uses roughly the same technology as in Denmark, one may compute total employment created by Danish wind turbine manufacturing.

These calculations include all indirect employment outside Denmark, related to e.g. imports of generators and gearboxes.

Global employment multipliers are not published at the detailed 117-sector level. In 1991 manufacturing of fabricated metal products

Table 4. Global direct and indirect employment from the installation of Danish wind turbines

	Gross output value per cent of turbine value	DS Sector No.	Manufactured in DS-sector	Gross output value 1995 million DKK	Employment multiplier 1991 pers/million	Employment multiplier 1995 **) pers/million	Total employment 1995 persons
Consultancy work etc. *)	7.9	83509	Business services	304	2.92	2.20	669
Foundations	4.5	50000	Construction	173	3.53	3.05	528
Electrical installation	1.9	50000	Construction	73	3.53	3.05	223
Grid connection, cable	10.9	50000	Construction	419	3.53	3.05	1,278
Transformer	2.6	38398	Other electrical supplies	100	3.76	3.01	301
Remote control system	0.6	38320	Telecom equipment	23	3.76	3.01	69
Road	1.3	50000	Construction	<u>50</u>	3.53	3.05	<u>153</u>
Private expenditure total	29.7			1,142			3,221
Grid reinforcement, estimate	6.6	***)	Constr. + other electrical	<u>252</u>	3.65	3.03	764
<b>Total</b>				<b>1,394</b>			<b>3,985</b>

\*) Consultancy etc. is 6 percentage points higher than in Denmark to account for developers, public administration etc.

\*\*) Employment multiplier has been adjusted with the growth rate of the previous 4 year interval

\*\*\*) Employment multiplier is the average of the construction industry and fabricated metal products

Global employment from Danish wind turbine manufacturing of 12,000 persons in 1995

Installation of Danish turbines worldwide creates another 4,000 jobs globally

Direct and indirect employment from windpower in Denmark has grown from 3,100 in 1991 to 8,500 in 1995 (cf. also table 3)

Employment in the windpower industry is larger than previously estimated

The import propensity in the sector is around the average for the fabricated metals sector

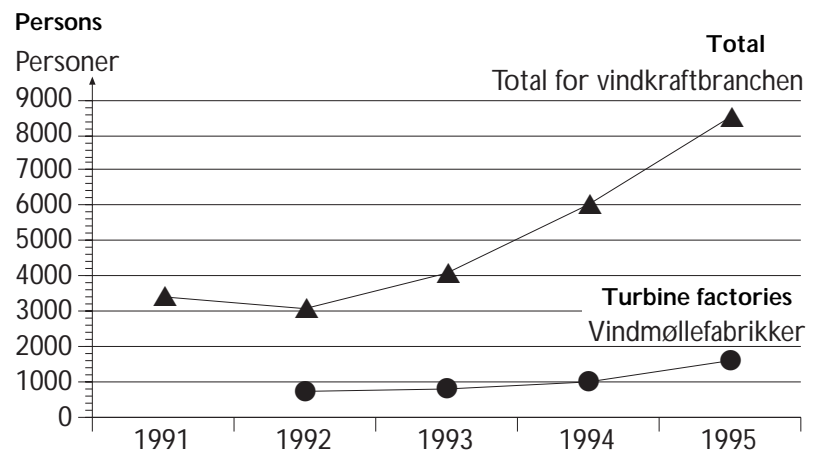
Thus we may use a simplified method of calculation

created 3.76 jobs per million DKK gross output value. Adjusting the coefficient to 1995 using the same rate of change as in the previous 4 years gives coefficient of 3.01.

Global job creation of Danish turbine manufacturing and component exports amount to 11,600. That figure should be adjusted upwards by some 5 per cent to account for the fact that machinery manufacturing has a 5 per cent higher labour content than the average for the fabricated metal products group.

Table 4 demonstrates that installation of Danish turbines abroad creates another 4,000 jobs abroad. The table has been produced using the same method as in table 1.

Figure 1. Direct and indirect employment from wind power in Denmark



## 10 CONCLUSIONS

The windpower sector in Denmark has previously estimated far lower figures for direct and indirect employment than this report.

Firstly, employment appears to be 2 to 3 times higher than what was previously assumed. A survey among the members of the Danish Wind Turbine Manufacturers' Association conducted in May 1995 revealed, however, that employment among the members of the association exceeded the total employment estimated for the industry as a whole.

Secondly, this report demonstrates that the sector has approximately the same import contents in its output as the average of the machinery and equipment manufacturers.

As has been demonstrated in section 3 one may omit the tedious calculations compensating for generator and gearbox imports. Using the average coefficients for fabricated metal products one obtains a result that differs by less than 5 per cent from the results in this report. Considering the fact that this note tends to overcompensate for imports, the results are for all practical purposes identical.

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